Electron Polarimetry Studies: Compton Scattering

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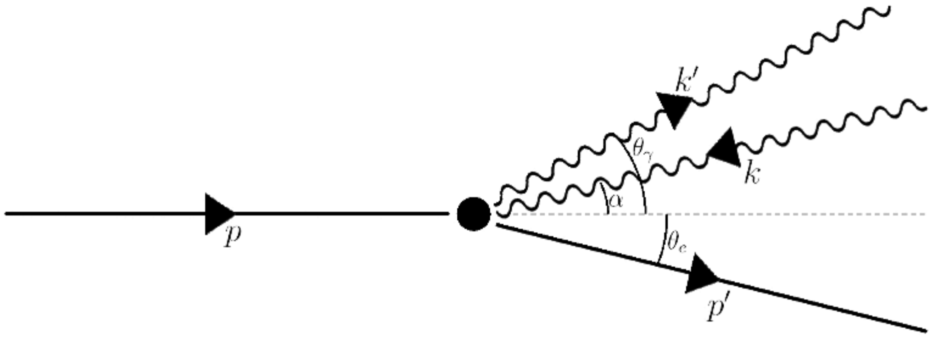
Intro to electron polarimetry

- need to measure polarization with ~1% uncertainty
- in the relevant energy range for the eic, use the method of compton backscattering
- can measure either the scattered photon or electron (or both)
- ideally we want to measure both longitudinal and transverse components
  - transverse polarization leads to a position asymmetry
  - longitudinal polarization leads to an energy asymmetry
- achieved by shining a laser on electron beam while flipping the helicity of the (circularly polarized) laser

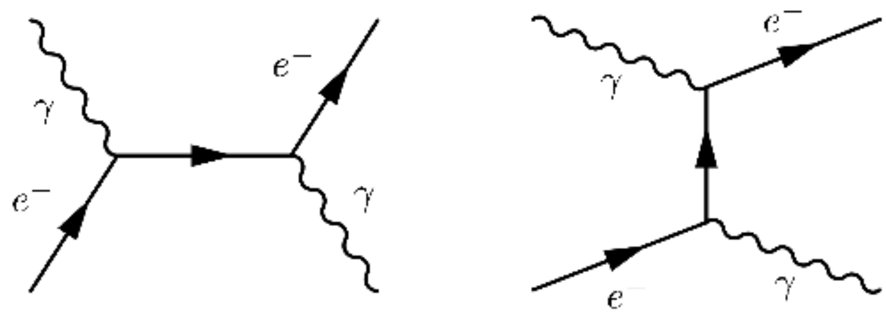
$$A_{\mathrm{exp}} = P_e P_\gamma A_\ell$$

Compton Scattering



- some references from which the following originates (and is the basis for the MC shown in the next few slides)
  - http://nuclear.uwinnipeg.ca/theses/dstorey_thesis.pdf
  - https://tel.archives-ouvertes.fr/tel-00920424/document
- note the following applies for $\alpha \approx 0$
- define some convenient kinematic variables:
  - $\rho = k'/k'_{max}$ is the scattered photon energy relative to the compton edge
  - $k'_{max} = 4ak\gamma^2$ is the maximum photon energy (compton edge)
  - $a = 1/(1+4k\gamma/m_e)$
  - k is the photon energy, E is the electron energy

Compton scattering cross section and longitudinal asymmetry



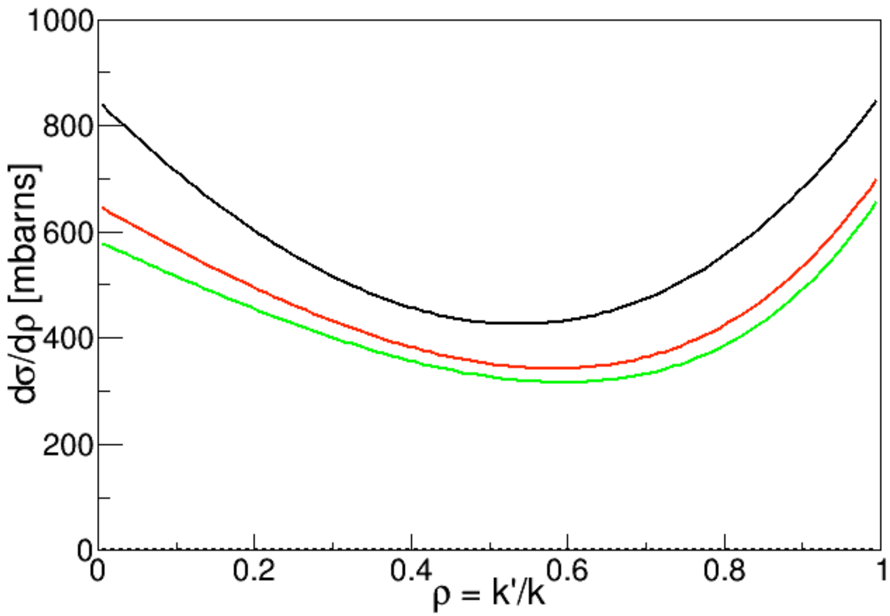
- QED calculation
- for laser crossing angle, α=0 and with respect to ρ (unpolarized):

$$\frac{d\sigma}{d\rho} = 2\pi r_0^2 a \left[\frac{\rho^2 (1-a)^2}{1-\rho(1-a)} + 1 + \left(\frac{1-\rho(1+a)}{1-\rho(1-a)} \right)^2 \right] \quad (1)$$

- The longitudinal asymmetry:

$$A_\ell = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{2\pi r_0^2 a}{\frac{d\sigma}{dp}} (1-\rho(1+a)) \left(1 - \frac{1}{(1-\rho(1-a))^2} \right) \quad (2)$$

Cross section and A_l distributions as a function of energy



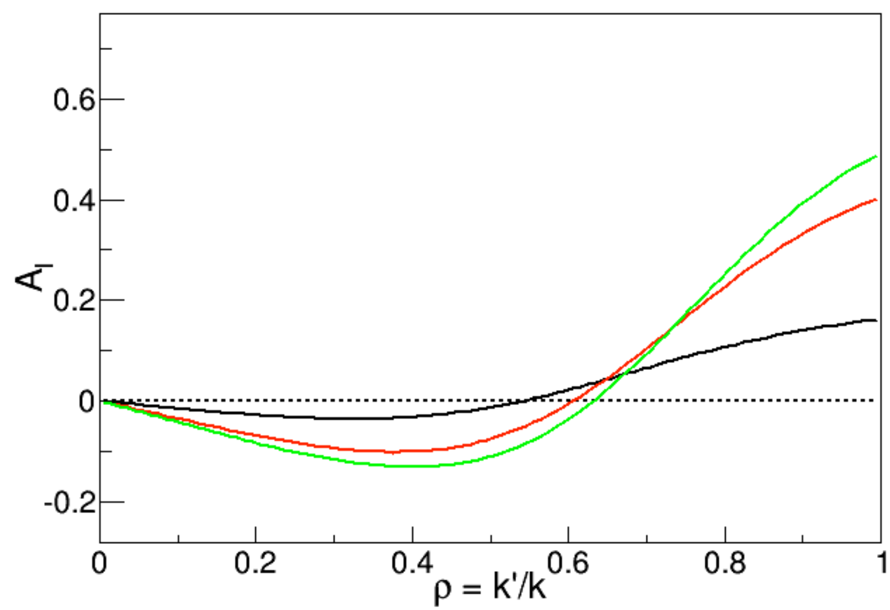
Integrated cross sections

- 5 GeV electron (569mb)
- 15 GeV electron (455mb)
- 20 GeV electron (418mb)

- laser at 2.33 eV

- max photon energy = 0.757 GeV
- max photon energy = 5.23 GeV
- max photon energy = 8.33 GeV

- min electron energy = 4.24 GeV
- min electron energy = 9.77 GeV
- min electron energy = 11.67 GeV

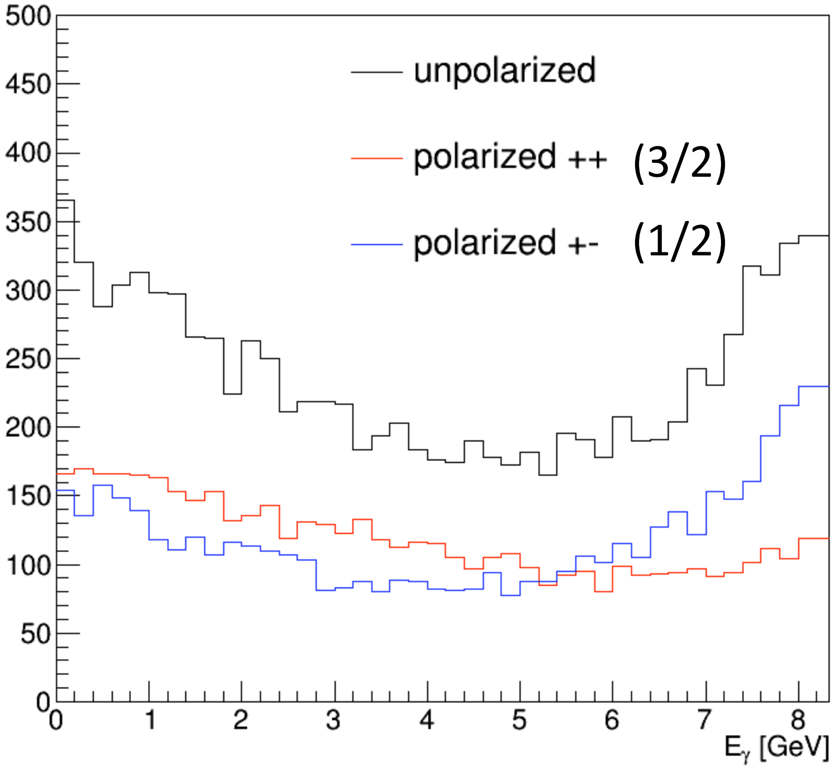


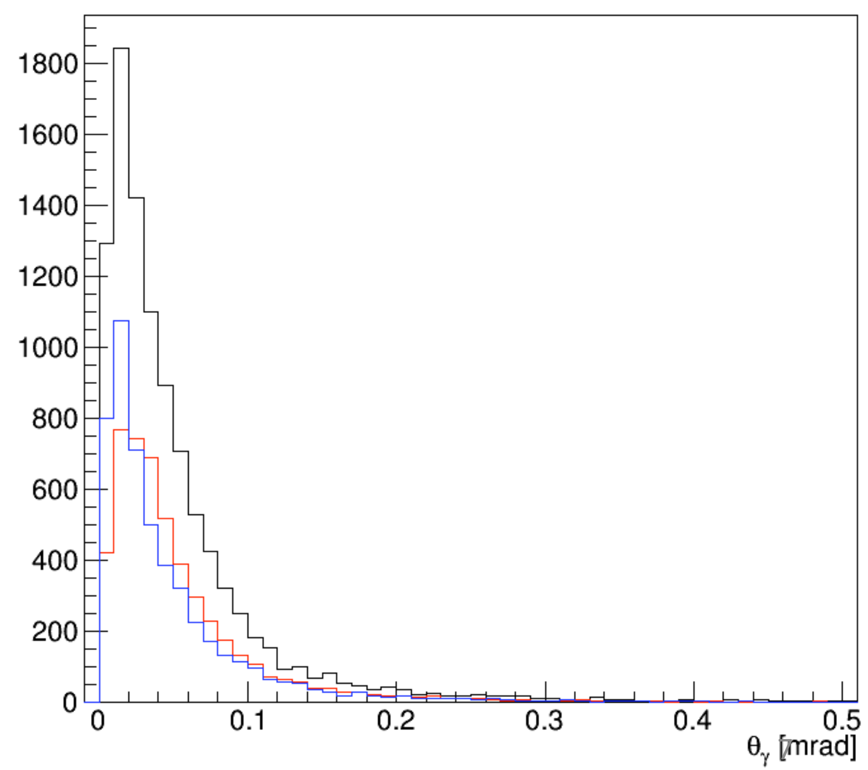
Compton MC generator (work in progress)

- code source /direct/eic+u/rmpetti/workarea/electron_polarimeter/comptonGenerator.C
- only longitudinal polarization built in at the moment
- inputs: nevents, e beam energy [GeV], laser energy [GeV], e polarization fraction
- basic algorithm:
  - pull random ρ value from Eq. 1 on slide 4 (or from the polarized distribution if desired…calculated from Eq. 1 and 2)
  - convert this to energy based on the compton edge for the e beam energy
  - calculate the scattering angle based on the scattered photon energy
- output: ascii file in same format as for DJANGOH
  - easy to input into EicRoot

Output of the generator

- generate 10,000 events for now
- E_e = 20GeV, $E_\gamma = 2.33\text{eV}$, $P_e = 0.8$, $P_\gamma = 1$





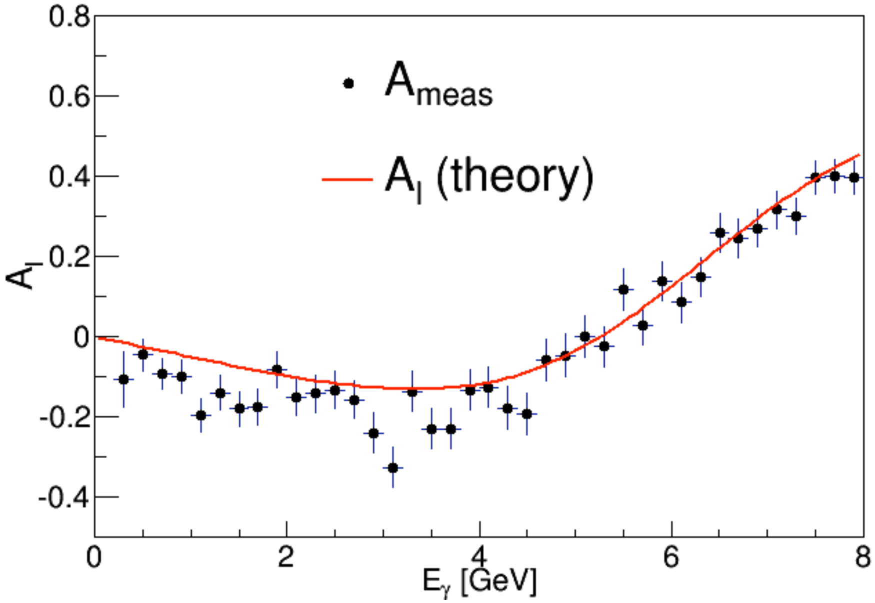
Simple extraction of polarization

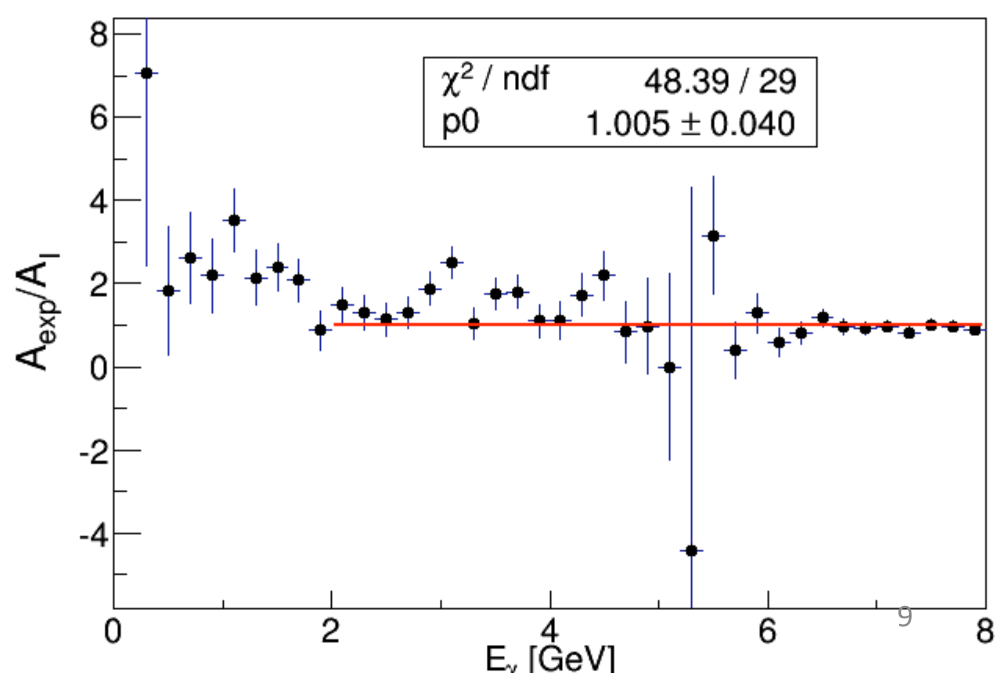
- focus on measuring the photon at the moment
- implement an "out of the box" calorimeter in EicRoot
- no implementation of machine lattice yet
- generate events with spin = 3/2 and ½ to separate files
  - note a mistake in event generation, generate with 100% polarized
    - will redo, but this is ok for proof of principal in getting code ready
- push simulation through entire sim chain
  - final output is energy clusters in emcal
- this simulates running in single photon mode
  - plot the measured asymmetry via the equation

$$A_{\exp} = \frac{\sigma^{3/2} - \sigma^{1/2}}{\sigma^{3/2} + \sigma^{1/2}}$$

  - divide by theoretical asymmetry (Eq. 2) to extract polarization

Measuring polarization in the simulation



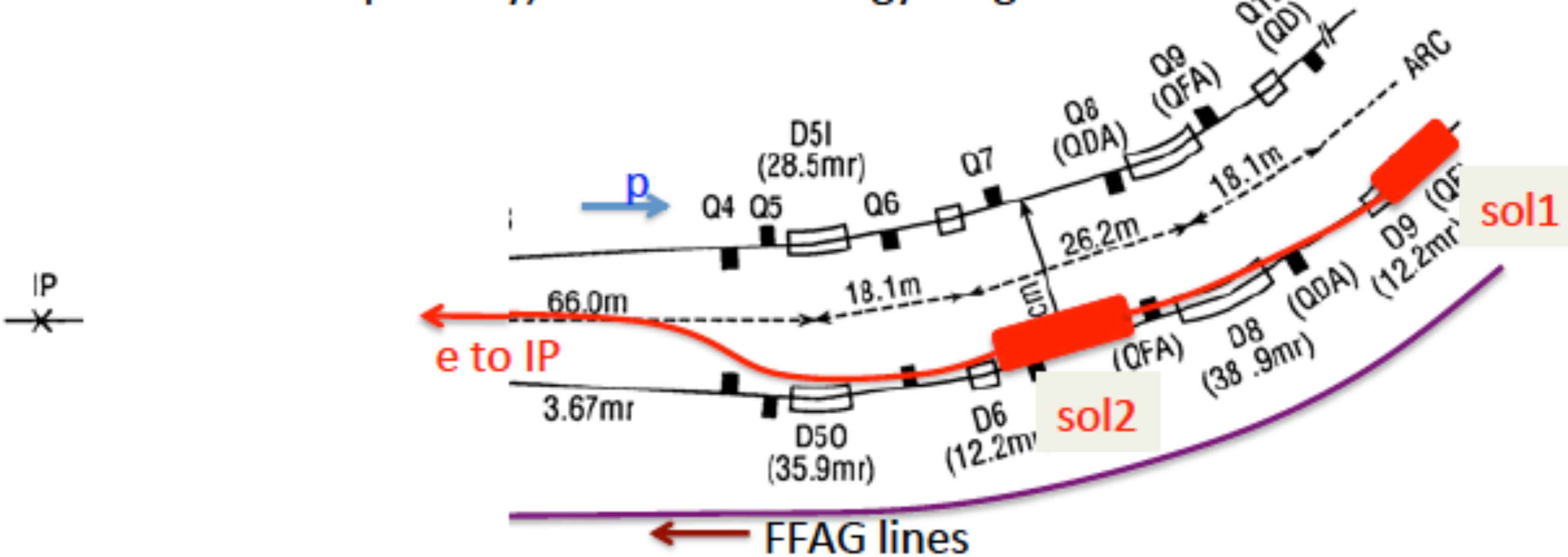


- extract a polarization of 1
- which is what was put into the simulation
- need to rerun with a more realistic 80% polarization

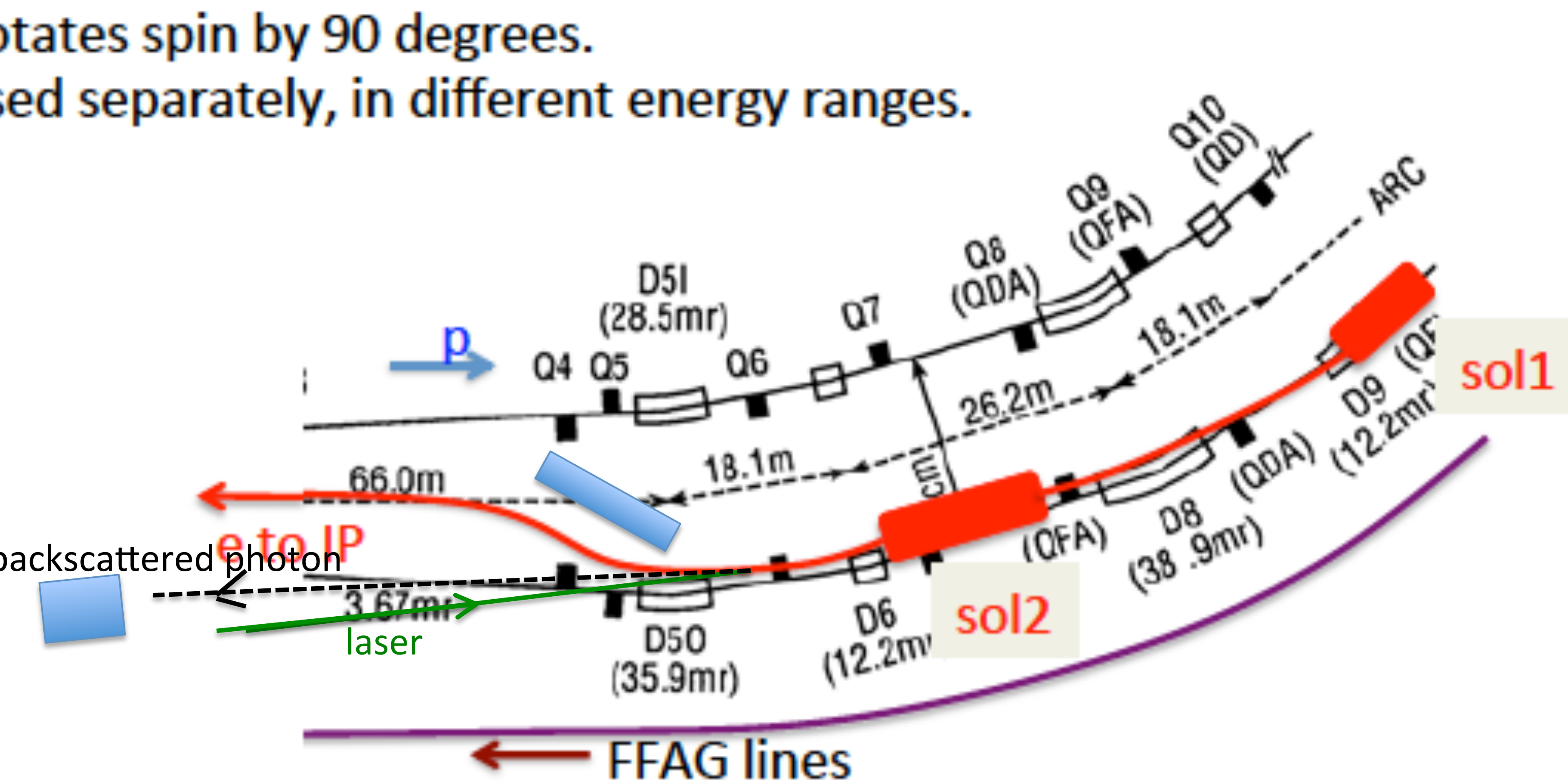
A bit on the physical implementation of the polarimeter

- design from Vadim

Each solenoid rotates spin by 90 degrees.
Solenoids are used separately, in different energy ranges.



A bit on the physical implementation of the polarimeter



- what is the beta function here?

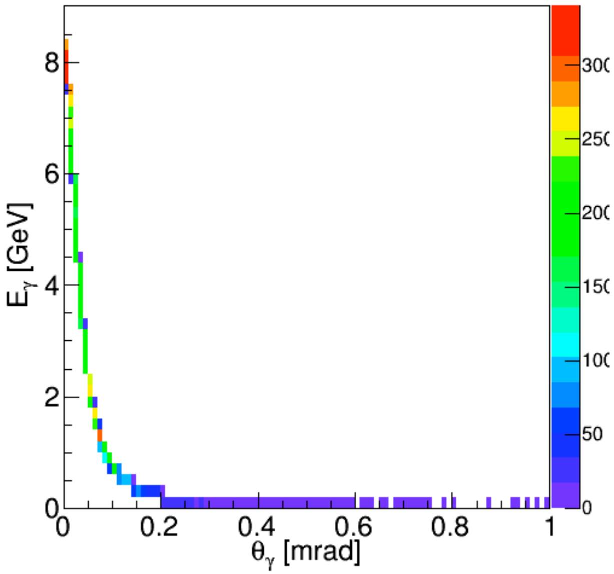
to do

- get the actual field setup for this section of the ring and implement into EicRoot
- get realistic placement of detectors
- redo current exercise for the electron
- investigate different algorithms to extract the polarization
- background studies
  - synchrotron radiation
- beam optics
  - beam divergence

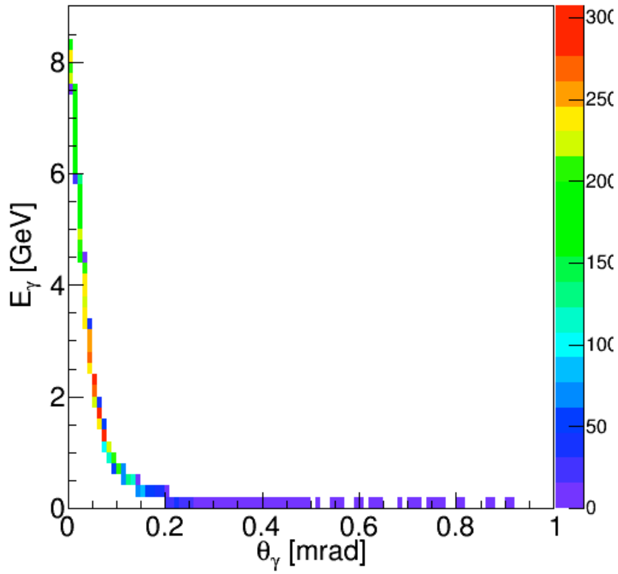
Backups

Scattered photon energy vs theta

unpolarized



spin 3/2



spin 1/2